



## RESEARCH DEPARTMENT

### AN ANALOGUE COMPUTER FOR AERIAL RADIATION PATTERNS

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**THE BRITISH BROADCASTING  
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## AN ANALOGUE COMPUTER FOR AERIAL RADIATION PATTERNS

### SUMMARY

An analogue computer has been constructed to calculate the horizontal radiation patterns of aerial arrays comprising a number of radiating elements mounted on a central support mast. The radiation pattern of a single element must be known, and from this the pattern for a number of identical elements round the mast may be calculated. The currents in the elements may have any desired amplitudes and phases.

The principle used is the addition of a number of audio-frequency voltages, each component representing the radiation from one element in a particular direction. By using a bank of rotary switches, the appropriate summations are made in turn for bearings at intervals which may be either  $7.5^\circ$  or  $15^\circ$ , the resultant being indicated on a meter. The computer may be adapted to other types of visual display.

### 1. INTRODUCTION

In designing an aerial for television or sound broadcasting in the v.h.f. band it is frequently necessary to achieve a horizontal radiation pattern (h.r.p.) of a prescribed shape. It may, for instance, be desirable to radiate a high power in certain directions in order to serve selected highly populated districts, and to restrict the power in other directions in order to minimize interference with stations working on the same channel.

In the preliminary planning stages it is the practice in the B.B.C. Research Department to prepare a templet relating to the proposed station; this templet takes the form of two field-strength polar diagrams which show the minimum desired and the maximum permitted values of effective radiated power (e.r.p.) in all horizontal directions. The shape of the h.r.p. of the aerial should lie between these two closed curves, and the required transmitter power can be calculated, knowing the e.r.p. and the gain of the aerial.

With the spread of television and v.h.f. sound broadcasting, the number of common-channel stations has steadily increased and, as a result, the requirements for individual stations have tended to become more exacting. In some cases a satisfactory pattern may be obtained by using the mast as an aperiodic reflector (with or without additional reflecting members) in association with a single radiating element. A more flexible method is to use in each tier of the aerial a number of radiating elements, the relative amplitude and phase of the currents in these elements being chosen to give the required shape of h.r.p. in the presence of the mast.

The h.r.p. of one element mounted on a supporting structure can, in some cases, be calculated; in any case it can be measured, for instance, by using a small-

scale model. To derive the radiation pattern when a number of similar elements are used it is necessary to calculate the vector sum of their individual patterns. If the required pattern is complicated in shape, the field must be determined for a large number of directions; furthermore, in the search for the simplest system meeting the requirements, it may be necessary to explore many combinations of the number and position of the elements, and of the relative amplitudes and phases of the currents they carry. This process can be very laborious and time consuming, whether by hand computation or by the assembly and adjustment of a large number of experimental models.

The "Aerial Radiation Pattern Analogue Computer" (ARPAC) described here was constructed to ease some of the difficulties mentioned above. It is designed to perform the task of calculating, from the radiation pattern of a single element, the radiation pattern for a number of identical elements; these may carry currents of any amplitude and phase, and may be disposed in different directions relative to the axis of the supporting structure, provided the spacing from the axis is the same.\*

## 2. PRINCIPLE OF OPERATION

Consider the plan view of an aerial system consisting of a number of similar elements disposed round a support mast, as shown in Fig. 1(a). The radiation from one element is known for a number of equally spaced directions at angles  $0, \Delta, \dots, n\Delta \dots$  (clockwise from the position of the element) in the form of a series of complex numbers  $(a_1 + jb_1), (a_2 + jb_2) \dots (a_{1+n} + jb_{1+n}) \dots$  respectively; the modulus of the complex number is the relative amplitude of the radiated field, and the argument is the relative phase referred to the axis of the mast. Let us suppose we have two elements as shown in Fig. 1(a) with element 2 at an angle  $r\Delta$  anti-clockwise from element 1, where  $r$  is an integer. In this case the resultant in direction 0, for elements fed with equal in-phase currents, is the sum of  $(a_1 + jb_1)$  from element 1 and  $(a_{1+r} + jb_{1+r})$  from element 2; for the direction  $n\Delta$  clockwise from 0 it is the sum of  $(a_{1+n} + jb_{1+n})$  and  $(a_{1+n+r} + jb_{1+n+r})$ .

Summations of this kind may be achieved by a rotary switch, as indicated in Fig. 1(b). Alternating potentials of amplitudes  $(a_1 + jb_1), (a_2 + jb_2) \dots$  are applied to the contacts taken in sequence, and two wipers are used with wiper 2 staggered by  $r$  contacts clockwise relative to wiper 1. A summation of the wiper potentials for the positions shown in the diagram yields the resultant radiation for direction 0. By moving both wipers one step clockwise the resultant for the direction  $\Delta$  clockwise from direction 0 is obtained; this process may be repeated to obtain the complete pattern at angular intervals of  $\Delta$ . Moreover, if the aerial elements are fed with currents  $(x_1 + jy_1)$  and  $(x_2 + jy_2)$  respectively, the required resultant for direction 0,  $(a_1 + jb_1)(x_1 + jy_1) + (a_{1+r} + jb_{1+r})(x_2 + jy_2)$ , is obtained if the wiper potentials are multiplied by the factors  $(x_1 + jy_1)$  and  $(x_2 + jy_2)$  respectively, before summing.

\*The computer may also be used (as explained in Section 3.5) for calculations involving two types of elements; for instance, elements having different spacings from the axis. However, to simplify the description it is assumed initially that the elements are identical and equally spaced from the axis.

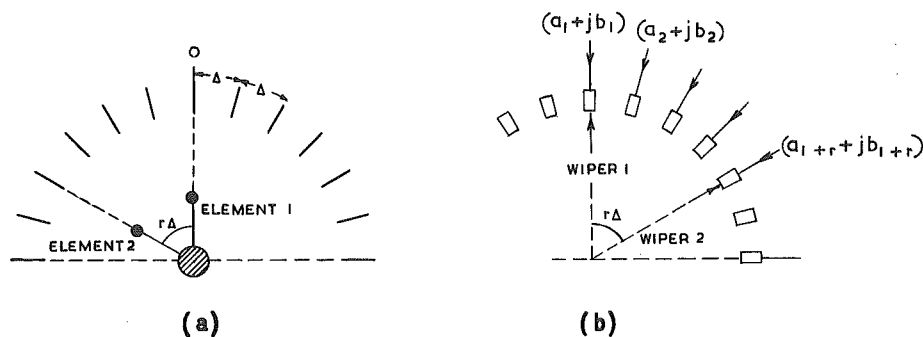


Fig. 1 - The addition of radiation patterns

In the computer described, this principle has been extended to provide for any number of elements up to a maximum of eight, the unit angle ( $\Delta$ ) being  $15^\circ$ . A group of telephone uniselector switches is used, one for each radiating element; the corresponding contacts are electrically paralleled and the wipers are staggered, by electro-mechanical control, in a pattern which forms the mirror image of the disposition of the radiating elements.

A block schematic of the computer is shown in Fig. 2. The source used is a 1 kc/s oscillator, each of the complex potentials  $(a+jb)$  being obtained by combining two quadrature components of appropriate amplitudes. The multiplication by

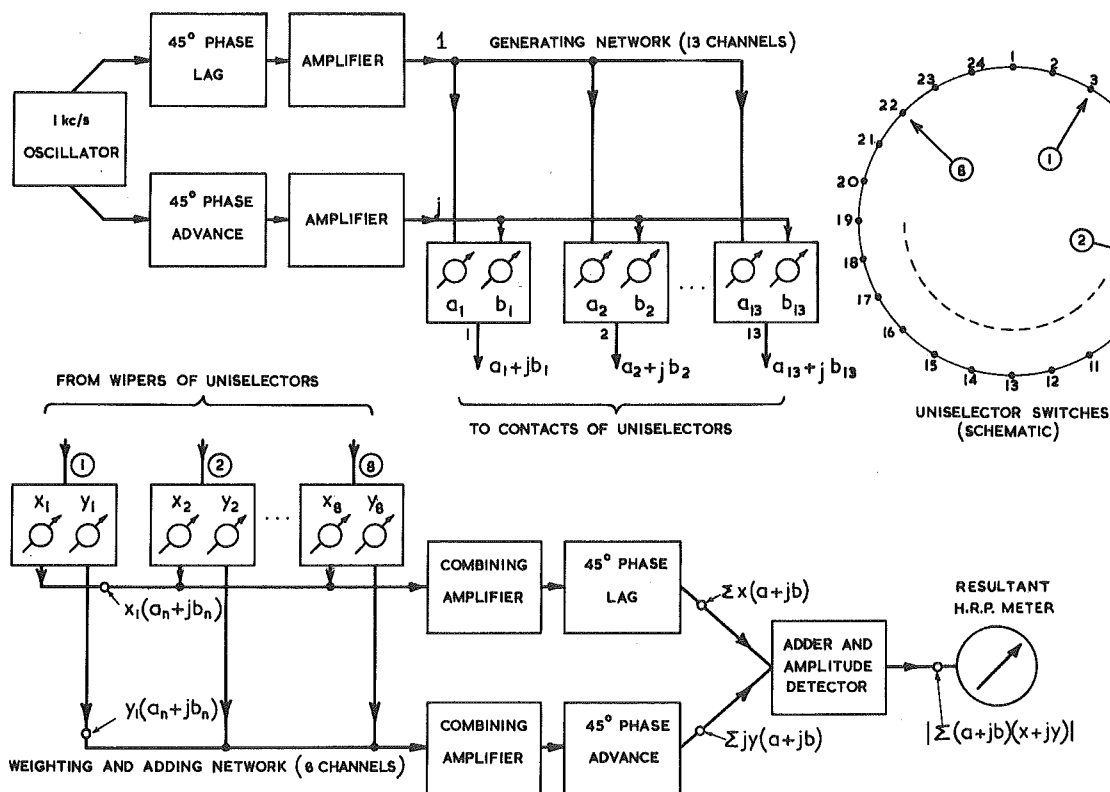


Fig. 2 - Block schematic

$(x + jy)$  is achieved by deriving fractions  $x$  and  $y$  of the output from a particular wiper; all the  $x$  and all the  $y$  components derived from the various wipers are added separately. The resultant  $y$  component is then advanced in phase by  $90^\circ$  relative to the resultant  $x$  component, and the two added. Since we require only the modulus of the resultant, a simple meter responding to the alternating potential can be used as the indicator; this displays  $|\Sigma(a + jb)(x + jy)|$  for a given direction, the summation covering the total number of elements in the array.

In operation, the values of  $a$  and  $b$  for each direction are first set up on the computer, the wiper orientations are adjusted according to the relative dispositions of the elements, and the weighting parameters  $x$ ,  $y$  are set up to correspond to the relative currents in the elements. The resultant radiation is then indicated on the meter, the wipers being moved one step at a time by operating a press button, so that a reading is obtained for each direction in turn; this operation will be referred to as "stepping".

The accuracy of indication of any radiation pattern is generally within 2% of the maximum; this limit of accuracy is set mainly by inequalities of nominally identical components, but slight variations of the "pattern" voltages with changes in the load presented by the switch circuits also contribute to the errors.

The switching process could also, of course, be done electronically; the electro-mechanical system was decided on because it did not entail any development and the equipment was urgently required.

### 3. CIRCUIT DESCRIPTION

A photograph of the equipment is shown in Fig. 3. The pattern-setting controls, which are set up to correspond to the parameters  $(a + jb)$ , are housed in

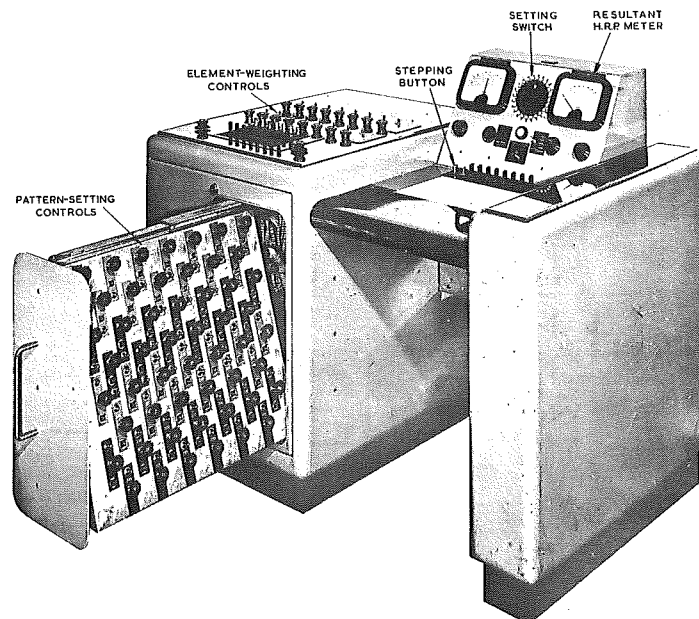


Fig. 3 - Photograph of computer

a sliding drawer on the left-hand side of the cabinet. The element-weighting controls, which are set up to correspond to the parameters  $(x + jy)$ , are on the top of the control desk on the left-hand side. The setting switch used to orient the uni-selector wipers is on the sloping panel, and the associated stepping button is below. The output is indicated on the right-hand meter, and the corresponding direction by one of a ring of lamps around the setting switch. Simplified circuit diagrams of various parts of the circuit are shown in Figs. 4 to 8.

### 3.1. Oscillator and Quadrature Circuit

A frequency of approximately 1 kc/s is generated by means of a Wien-bridge oscillator; the circuit diagram is shown in Fig. 4. Since the frequency affects the characteristics of the phase-shifting networks, it is adjustable over a small range by means of a pre-set resistor in one of the reactive arms of the bridge. V14 and V15 form a resistance-capacity coupled amplifier, the output of which is fed back to the bridge circuit. A thermistor is used as one of the resistive bridge arms; this stabilizes the oscillator amplitude and also ensures that the amplifier works under quasi-linear conditions, so that the harmonic distortion of the output waveform is kept low (the total harmonic distortion is about 0.5%).

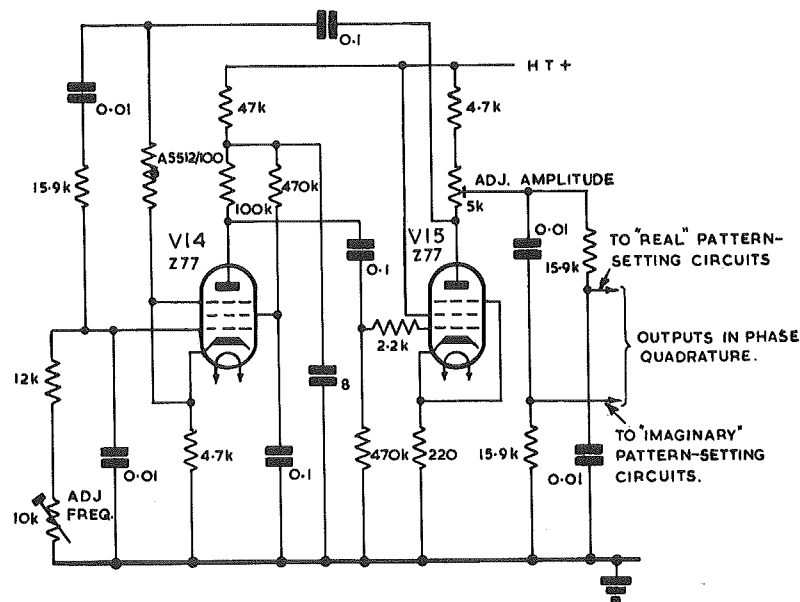


Fig. 4 - Oscillator and quadrature circuit

The oscillator is coupled to two cathode followers through resistance-capacity phase-shifting circuits such that one output leads and the other lags by  $45^\circ$ ; two outputs of the same amplitude in phase quadrature are thus available.

### 3.2. The Pattern-Setting Controls

The outputs from the cathode followers, V16 and V17 in Fig. 5, are each connected to a transformer with a centre-tapped secondary balanced to earth, giving

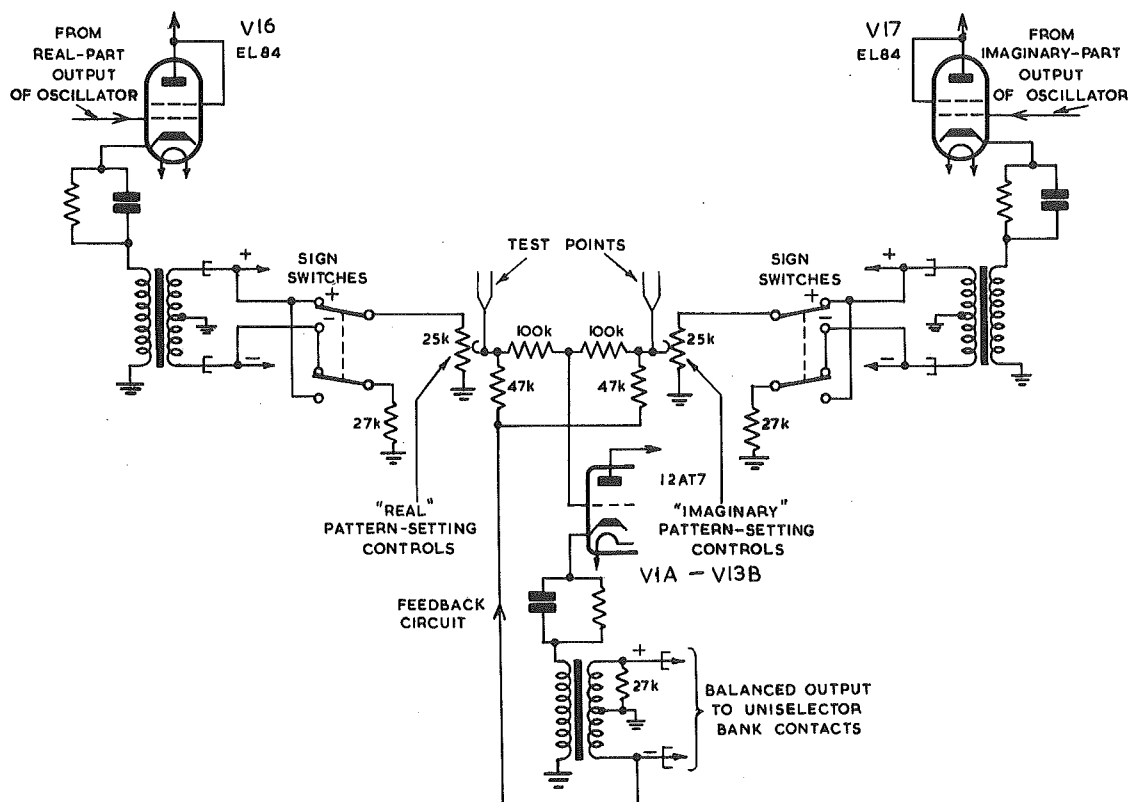


Fig. 5 - Typical pattern-setting circuit

four outputs which have relative phase angles of  $0^\circ$  and  $180^\circ$ ,  $90^\circ$  and  $270^\circ$ . These energize banks of potentiometers which are set to give output voltages proportional to the real and imaginary components of the complex radiation pattern of a single element; the  $0^\circ$  and  $180^\circ$  phases correspond to positive and negative real components, and the  $90^\circ$  and  $270^\circ$  phases to positive and negative imaginary components. There are thirteen pairs of potentiometers, corresponding to an arc of  $180^\circ$  at  $15^\circ$  intervals; this number is sufficient because, as explained later, we can take advantage of the symmetry of the radiation pattern of the element. Each potentiometer is associated with a "sign" switch which selects the appropriate phase, and at the same time loads the unused phase with a resistance equivalent to the potentiometer, thus maintaining constant and symmetrical load conditions on each cathode-follower transformer. The setting-up process is carried out with the aid of the output meter, as explained in Section 3.4.

The output from each pair of potentiometers is connected through a resistive mixing circuit to a cathode follower, the output load of which is a transformer with an earthed centre-tap on the secondary. Each cathode follower therefore provides an output which is proportional to  $(a + jb)$  for one given direction. To reduce the effect of the change in source impedance presented to the mixing circuit by the potentiometers, feedback is employed from one side of the transformer output winding; the other side is loaded with a resistor equivalent to that of the feedback circuit,

in order to preserve symmetry. The feedback also has the advantage of electrically decoupling the two sliders of the potentiometers.

The balanced output from the cathode follower associated with each pair of potentiometers is fed to two banks of contacts of the rotary uniselector switches. The thirteen cathode followers are connected to contacts 1-13 (corresponding to directions  $0^{\circ}$ - $180^{\circ}$ ), contacts 14-24 (corresponding to directions  $195^{\circ}$ - $345^{\circ}$ ) being normally connected through a twenty-two-pole two-way switch to contacts 12-2, respectively. This switch permits the polarity of signals fed to contacts 14-24 to be the same as that for contacts 12-2 (the requirement for vertical\* and tangential elements), or to be reversed (the requirement for radial elements). This changeover is required because for vertical or tangential elements the radiation is symmetrical, whereas for radial elements it is skew-symmetrical, with respect to a plane through the centre of the element and the axis of the mast.

### 3.3. The Element-Weighting Controls

The outputs from the uniselector wipers are applied to the element-weighting potentiometers (shown in Fig. 6), to permit the amplitude and phase of the current

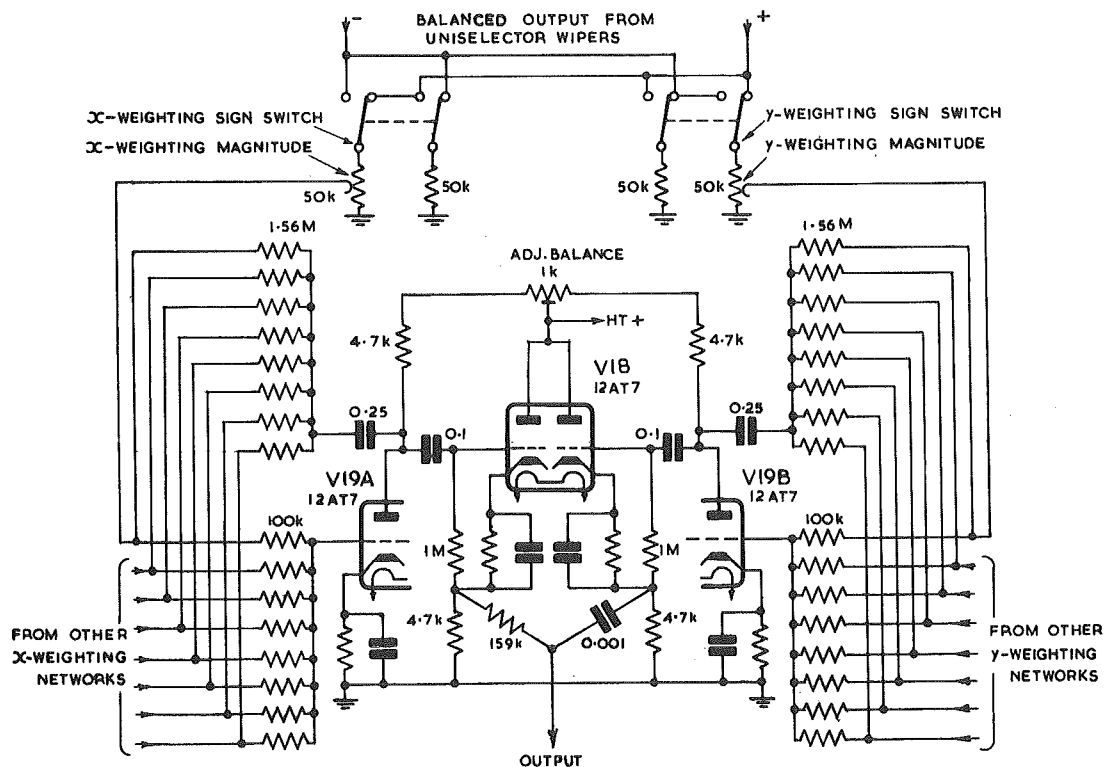


Fig. 6 - Element-weighting and adding circuit

\*The axis of the system is taken to be vertical.

in each element to be taken into account. Two potentiometers are associated with each element, one corresponding to the real and the other to the imaginary component ( $x$  and  $y$ , respectively) of the current in the element. The potentiometers are set up by means of a calibration key which disconnects the normal circuit, applies a d.c. supply, and connects the wiper to a d.c. meter.

The output voltages from all the  $x$ -weighting potentiometers are combined in a resistive circuit, and the sum amplified by one half of the double triode, V19A in Fig. 6. In the same way the other half, V19B, amplifies the sum of the outputs from the  $y$ -weighting potentiometers. In both cases a resistive feedback network is provided to reduce interaction between the weighting controls, as in the circuits associated with the pattern-setting potentiometers. The outputs of the adding networks are applied to two cathode followers (V18 in Fig. 6); the two cathodes are connected by a network which advances the phase of the  $y$ -output relative to that of the  $x$ -output by  $90^\circ$  before adding.

### 3.4. The Output Circuit

The output circuit is shown in Fig. 7. After amplification and detection the modulus of the output is indicated on a meter. As it is usually convenient to have the output normalized with respect to the maximum value, the amplifier is provided with an adjustable gain control; this enables the maximum reading to be set to full scale on the meter. The effective range can be extended by means of a switch which provides  $\pm 6$  dB steps in the indication.

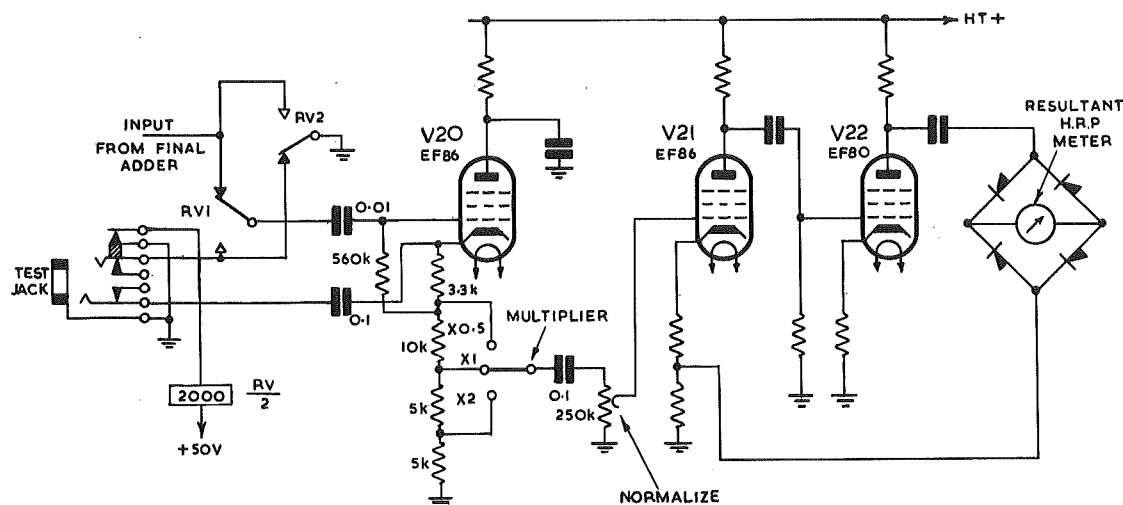


Fig. 7 - Output circuit

The output circuit is also used in adjusting the pattern-setting controls. Connexions to the wipers of these controls are provided by the test points, which are shown in Fig. 5. These can be connected to the output circuit by means of a test lead, the controls being adjusted in turn to the required value; the need for calibrated potentiometers is thus avoided. Moreover, the effect of the finite load on each potentiometer is automatically taken into account. The test lead is made

of double-screened cable, the inner screen being connected to the cathode of the first amplifying valve, and the outer screen to earth. This prevents hum and other stray pick-up, while the double-screen arrangement reduces the effective stray capacitance of the screened cable.

### 3.5. Operating Facilities

In the design of some aeralis the radiation in a limited number of directions is of special importance. It is then convenient to be able to derive these values rapidly, in order to decide whether it is worth while exploring the complete radiation pattern. This facility is provided by a "hunt" key which rotates the whole set of elements until element 1 is in the selected position indicated by the window of the setting switch.

It is sometimes necessary to work on two independent problems at the same time. Two banks of pattern-setting potentiometers (bank A and bank B) have, therefore, been provided, and either may be used for the basic type of computation described; one radiation pattern can be "stored" while the other is being used, thus avoiding repeated setting-up of the same patterns.

Banks A and B may also be used in association, in a number of ways. Bank B may be set up to correspond to the radiation pattern of a single element at bearings differing by  $7\frac{1}{2}^\circ$  from those of the main bank; it is thus possible to obtain the radiation pattern of the array at angular intervals of  $7\frac{1}{2}^\circ$ . Alternatively, the two banks may be used when the aerial element has an asymmetrical radiation pattern. The pattern for the range of bearings  $0^\circ$ - $180^\circ$  is set up on bank A and that for the range  $195^\circ$ - $345^\circ$  on bank B. Again, if bank A potentiometers are set up to correspond to the radiation pattern of one type of element, and bank B to correspond to that of a different type (for instance, an element having a different spacing from the axis) the radiation patterns of combinations of such elements can then be derived.

In passing, it may be mentioned that the speed of setting up could be increased, and at the same time the accuracy improved, by using tapped transformers in place of the pattern-setting potentiometers; three transformers in place of one potentiometer would offer the facility of rapid setting to an accuracy of 0.1%, but at the expense of circuit complication. A combination of transformers and potentiometers is also possible.

### 3.6. Switching Control Circuit

A simplified circuit diagram of the switching control system is shown in Fig. 8. It is intended to demonstrate only the principle of setting, stepping and associated facilities; a great deal of the inter-connecting circuitry has, therefore, been omitted.

The eight uniselectors are designated A ... H, but for clarity their circuits are omitted where repetitive in character. In the description that follows, it is assumed that all eight uniselectors are in operation; in practice, however, the bank-selector switches are arranged to keep in circuit only those required for the number of elements in the array.

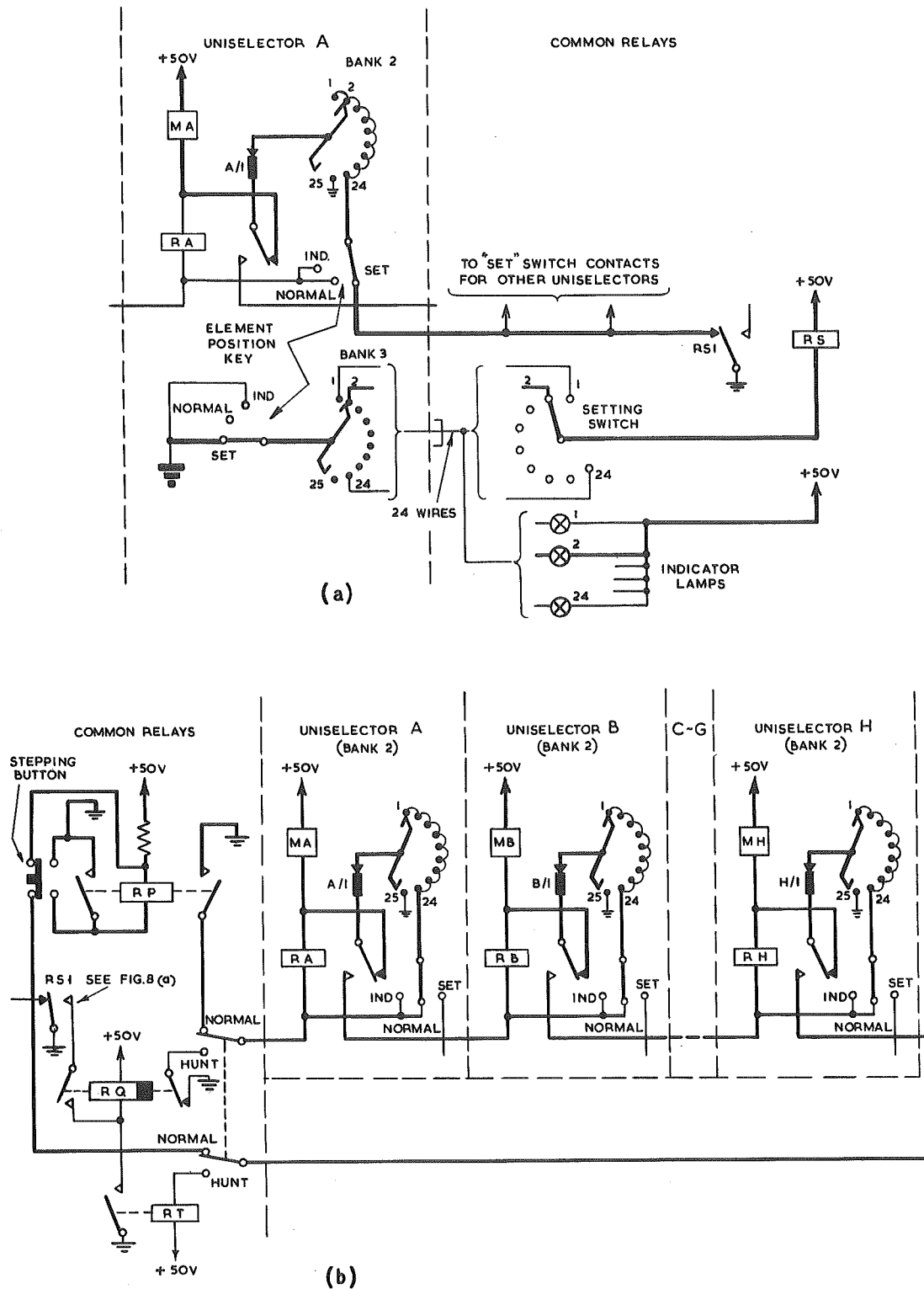


Fig. 8 - Simplified circuits for switching control

### 3.6.1. Uniselectors

Each unislector has eight banks of contacts, with twenty-five contacts in each bank, distributed over an arc of just under  $180^\circ$ . It has a rotating shaft, located at the centre of the arc of contacts, carrying eight wipers and slip rings; it therefore acts as a twenty-five-way eight-pole switch. Current is conveyed to the wipers by means of spring-wire brushes. All wipers are double-ended, i.e. each has two contacts  $180^\circ$  apart; thus, when one end of the wiper leaves contact 25, the other moves on to contact 1, so that each wiper connects with all contacts twice per revolution of the shaft.

The shaft is driven by means of a fifty-tooth ratchet wheel and pawl. It is operated by an electromagnet (MA ... MH in Fig. 8(b)) which lifts the pawl over one tooth, against the pull of two springs. On release of the magnet the springs restore the pawl and in so doing move the wipers on by one step; the wipers thus step forward only when the magnet is released, not when it operates. A fixed detent prevents backwards rotation, and a fixed stop locks the pawl against the ratchet wheel when the magnet is released, so preventing over-shooting. Just before the pawl passes over the edge of a tooth on the ratchet wheel, a pair of auxiliary contacts (A/1 ... H/1 in Fig. 8(b)) is opened by an extension of the magnet armature; they close again when the magnet is fully released. One of the main purposes is to enable the uniselectors to step round repeatedly as long as a voltage is applied to the electromagnet in series with the auxiliary contacts; when the unislector is correctly adjusted, self-driving occurs at a speed of 50-60 steps per second. Of the eight banks of contacts, two are used for switching control purposes, and four are used in the computing circuits; the banks of each unislector have the following functions:

|                            |                                                            |
|----------------------------|------------------------------------------------------------|
| Bank 2 (Bridging wiper)    | Stepping                                                   |
| Bank 3                     | Hunting, setting and position indicating                   |
| Bank 4 }<br>Bank 5 }       | Balanced input from pattern-setting<br>controls of bank A* |
| Bank 6 }<br>Bank 7 }       | Balanced input from pattern-setting<br>controls of bank B  |
| Banks 1 and 8 are not used |                                                            |

### 3.6.2. Setting and Lamp Indication

Fig. 8(a) is a simplified circuit diagram showing only those parts connected with initial setting and indication of the wiper positions. With the element-position key of one of the uniselectors in the "set" position, as shown in the diagram for unislector A, the contacts of bank 2 are earthed via the contacts of relay RS. (The reason for the direct earthing of contact 25 is given later.) The wiper of bank 3 is also switched to earth. Under these conditions the unislector self-

\*When computing with elements having an asymmetrical pattern, unislector banks 4 and 5 have inputs derived from both A and B pattern-setting controls.

drives until the wiper position corresponds to the setting-switch position. An earth is then applied to relay RS via the setting switch and the wiper of bank 3; this disconnects the bank 2 contacts from earth and further stepping of the unselector is prevented.

The contacts of bank 3 are also connected to the 50-volt supply via a set of twenty-four indicator lamps. These are arranged in a ring round the setting switch, and indicate the bearing which corresponds to the wiper position. The "indicate" position of each of the element-position keys allows a lamp to light according to the position of the element corresponding to the key, but does not initiate the setting operation just described.

### 3.6.3. Stepping Circuit

Fig. 8(b) is a simplified diagram of the circuit arrangement for stepping the uniselectors. When the stepping button is pressed relay RP operates and closes two pairs of contacts. One pair prevents the release of RP until the last unselector has operated; the other applies an earth to the input of unselector A. This causes the magnet MA to operate through the closed contacts A/1. At this time the coil of the relay RA is short-circuited and is, therefore, inoperative. As the unselector pawl falls over a tooth on the ratchet wheel, contacts A/1 open, causing the electromagnet MA to release and move the wipers of unselector A one step. (The impedance of MA is small compared with that of RA.) At the same time relay RA operates, preventing any further operation of the electromagnet and applying an earth to the input of unselector B via the re-made contacts A/1; a similar cycle is then repeated for unselector B. The stepping process continues until relay RH operates; provided the stepping button is released the RH contacts short-circuit relay RP, and so release it. The relays RA ... RH are then released in preparation for the next operation of the stepping button.

This arrangement ensures that only one step can be made at a time and that all uniselectors have time to make one step, independent of the time for which the stepping button is pressed. Furthermore, the steps are made sequentially rather than simultaneously, in order to reduce the power consumption to that of one unselector only.

As only twenty-four of the twenty-five contacts are required, any unselector which has reached contact 25 must be automatically stepped one further step to contact 1, without impulsing the next unselector. It is for this reason that contact 25 is, in each case, provided with a direct connexion to earth as shown in Fig. 8(b). Suppose unselector A wiper arrives at contact 25. All the subsequent selectors then operate and on release of the stepping button the relays are released as before except that, when RA releases, the earth on contact 25 causes unselector A to step once again; the subsequent selectors, however, do not operate since there is no input earth connexion to pass on. Similarly, any unselector which steps on to contact 25 is automatically stepped on to contact 1 as the last stage in the stepping cycle.

### 3.6.4. Hunting

Hunting is the process of continuously stepping the uniselectors as a group, as distinct from taking one step at a time, thus enabling the position for a selected

bearing to be reached quickly. The element-position key for element 1 is kept switched to the "indicate" position, thus earthing the bank 3 wiper of unselector A.

When the hunt key is operated an earth is applied to the bank 2 contacts of unselector A, as for stepping, but via the contacts of relay RQ (Fig. 8(b)). In addition, a contact of relay RH associated with the final unselector is connected to relay RT which, in turn, controls the operation of relay RQ. The uniselectors then form a ring-type circuit in which the completion of one stepping cycle initiates the next cycle. Thus, the completion of one cycle is terminated by the energizing of relay RQ which removes the input earth. The output earth from RH is then removed and the next cycle is initiated by the slow-release relay RQ which re-applies the earth to unselector A a short time afterwards.

Repeated stepping continues until the desired hunt position, which is controlled by the setting switch, is reached. When the earthed wiper of bank 3 arrives at the setting switch position, relay RS operates and terminates the hunting process by causing relay RQ to lock in, instead of slowly releasing.

#### 4. THE COMPLEX PATTERN OF A SINGLE ELEMENT

The raw material on which the computer operates is the h.r.p. of a single element of the array, expressed as a set of complex numbers. In idealized cases the radiation pattern can be calculated. For instance, a theoretical result is available for a doublet mounted on an infinitely-long perfectly-conducting cylinder;<sup>1</sup> this applies also to a perfectly-conducting cylinder of finite length provided it extends sufficiently far beyond the radiating elements. This result has been extended to cover the cases of vertical and tangential half-wave dipoles, and of radial quarter-wave unipoles, mounted on a cylinder; a set of tables giving the complex-number patterns for a range of cylinder radii and dipole spacings has been prepared, using a digital computer.<sup>2</sup>

A regular polygonal mast can be regarded as equivalent to a cylinder having the same capacity per unit length, provided the cross-sectional area is sufficiently small. An approximate theoretical method has been published for polygonal masts of large cross-sectional dimensions.<sup>3</sup>

In those cases where a theoretical result is either not available or difficult to compute, the complex radiation pattern may be measured,<sup>4</sup> for instance by using a small-scale model.

If the radiating elements are of a simple type (for example half-wave dipoles) the effect of mutual interaction between them is automatically taken into account by specifying the currents in individual elements, although the realization of the correct current ratios remains a problem for the designer of the distribution feeder system. However, calculations based on the addition of element patterns do not in general include the effect of re-radiation from the supporting arms, or from the elements themselves if these are of a complex type. Fortunately, these effects are negligible in many practical cases. Moreover, in certain other cases, namely when similar elements are disposed at equal angular intervals around the mast, the pattern of one element may be determined experimentally in such a manner that re-radiation effects are included.

The computer can also be used if the radiating elements consist of longitudinal slots in a cylindrical mast. Here, in the case of half-wave slots, the feed voltage rather than the feed current must be regarded as determining the weighting factor; this takes account of mutual interaction, being analagous to specifying the current in the case of half-wave dipoles. Sinclair<sup>5</sup> has given a theoretical result for the pattern of a longitudinal slot in a cylinder.

## 5. THE CONVERSE PROBLEM

The computer described assists in solving problems only on a "trial and error" basis; the operator feeds in a proposed arrangement and the computer gives the performance. If the result is unsatisfactory the operator, guided by judgment and experience, feeds in a different proposal and so on, until a satisfactory solution is obtained.

It would be much better if a machine could be designed to solve the converse problem, namely to find the simplest way of achieving a prescribed radiation pattern. Although this is theoretically possible there is not a unique solution, and finding the simplest system which satisfies the requirements presents formidable difficulties.

It is clearly unnecessarily restrictive to specify the precise shape of the radiation pattern; a tolerance in the e.r.p. is usually permissible, and it is desirable to take advantage of this to achieve the most economical design. The tolerance may be large in some directions and small in others, but it would entail great complication to make a machine exercise judgment in this respect. Since only the modulus of the radiation pattern need be specified, the best a computer can do is first to calculate the pattern for a chosen number of radiating elements, and then to derive a factor proportional to the overall deviation from the required pattern; some means would then have to be devised to adjust the weighting controls to minimize the deviation factor. (The deviation calculation could be processed to correspond to the degree of importance of the deviation in different directions.) The process is then repeated for an increased number of radiating elements until a satisfactorily small overall deviation is achieved. There is an added difficulty in that, for a given number of radiating elements, there may be more than one condition corresponding to a minimum deviation (in the mathematical sense), and it is necessary to search for the smallest minimum. Again, a particular solution found by the computer may entail relationships between the currents in the radiating elements which are difficult to achieve with practical circuits. These difficulties suggest that the best compromise may well be a simple computer of the type described, the operator exercising judgment in deciding the type of array to be investigated.

If required, the computer may be used in conjunction with any conventional visual display of the type used to show experimental patterns of aeri-als—for example, a polar display with a long-persistence cathode ray tube.

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